

Simulation of Call Admission Control in Multi-Traffic WCDMA System

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Abstract

Wideband Code Division Multiple Access (WCDMA) is the multiple access technique used in the third generation of mobile telecommunication (3G) systems. Capacity of this technique does not have an exact limit. The maximum capacity of WCDMA depends on current interference in the system. However, high interference causes the system a degradation of quality-of-service (QoS). Therefore, a mechanism to suppress the interference is vital. Call Admission Control (CAC) is a mechanism capable for maintaining the interference below a threshold. This report presents a basic simulation description necessary for demonstrating a simulation of a simple WCDMA system with CAC. The report includes some fundamental theories about a WCDMA system, traffic modeling, and CAC algorithms. Some simulation results are also given. The simulation results show that the blocking probability depends on the average number of users and thresholds. The results also show that much data traffic is blocked although the capacity is still available. This leads us to realize the importance of a mechanism to handle data traffic in the multi-traffics WCDMA system.

1. Introduction

Wideband Code Division Multiple Access (WCDMA) is the air interface of the third generation of mobile telecommunication (3G) systems. Users in a WCDMA system share the same radio channel to transmit and receive signals. Additional user creates interference into the channel. The increased interference leads to a decrease of signal-to-interference-ratio (SIR) of every user sharing the same channel. Lower SIR means higher bit-error-rate (BER), resulting in lower quality-of-service (QoS). Therefore, the WCDMA system requires a mechanism to maintain the interference level below a threshold level.

The capacity of WCDMA does not have an exact limit; this characteristic is also called “soft-capacity”. The system may accept a large number of calls. As mentioned earlier, more users mean an increase of interference.

Consequently, the improper admission may result in a degradation of the system’s QoS. Thus, the mechanism for controlling admissions to the system is vital for WCDMA systems.

Call admission control (CAC) is a mechanism capable of maintaining the interference level below the threshold. It decides whether a new call arriving to a cell will be admitted or rejected. Several CAC algorithms have been purposed e.g. in [2] and [3]. This report considers two CAC algorithms. They are the load based call admission control (LB-CAC), and the noise-rise based call admission control (NB-CAC).

The remaining sections in this paper are organized as following. Section 2 reviews basic theories of WCDMA loads. Section 3 describes simulation methods used in this simulation. Two CAC algorithms are then explained in section 4. Simulation results are presented in section 5. Section 6 concludes this work. Finally, some future works are presented.

2. Load factor and noise-rise

Both admission control algorithms in this simulation based on the load factor calculation. The equation to calculate the load factor is:

$$\Delta\eta = L_j = \frac{1}{1 + \frac{W}{SIR_j \cdot R_j \cdot v_j}} \quad (1)$$

When W is the total bandwidth of the system (fixed as 3.64 mbps in this simulation), SIR_j is the required carrier-to-interference ratio of the j -th user, R_j is the data rate of the j -th user, and v_j is the activity factor (assume 0.67, typical value is between 0.5-0.67 for voice traffics and 1.0 for data traffics [1]).

The total load factor in the WCDMA uplink is calculated from the following Equation.

$$\eta_{ul} = (1+i) \sum_{j=1}^K L_j \quad (2)$$

when i is other cells to own cell interference ratio (set as 0.65, [1])

Figure 1 shows the load factor-increase versus the numbers of voice-traffic.

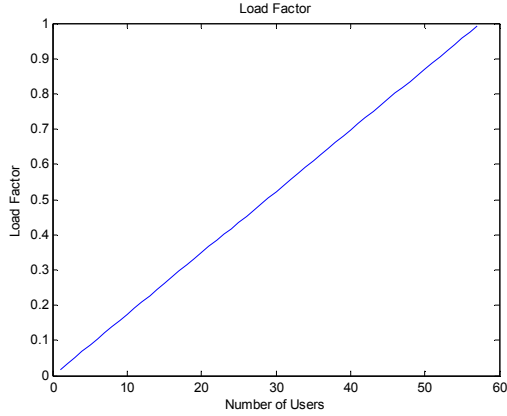


Figure 1 Load-factor characteristic

The WCDMA system is limited by the interference level. In [1], the authors define the ratio of the total received power (e.g. at base transceiver station, BTS) to the thermal noise power as the “noise-rise”.

$$Noise\ rise = \frac{I_{total}}{P_N} = \frac{I_{total}}{I_{total} - (1+i) \cdot \sum_{j=1}^N P_j} \quad (3)$$

when I_{total} is the total interference, P_N is the thermal noise and P_j is the power of j -th user .

P_j is a function of the load factor as shown below [1]:

$$P_j = I_{total} \cdot L \quad (4)$$

From Equation 2, 3 and 4, the noise-rise can be defined in the term of the total load factor as:

$$Noise\ rise = \frac{1}{1-\eta_{ul}} \quad (5)$$

Hence, the ratio of the interference over the thermal noise in decibel (dB) is:

$$Noise\ rise = -10 \cdot \log(1-\eta_{ul}) \quad (6)$$

The following Figures show the characteristic of noise-rise-increase versus the numbers of voice-traffic:

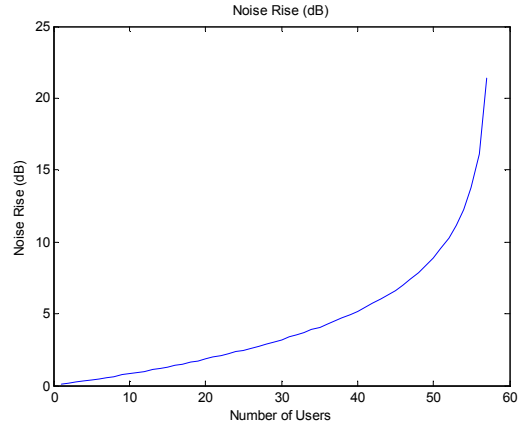


Figure 2 Noise-rise characteristic

Note that Figure 1 and Figure 2 are simulated by based on the simulation of a system where has only voice traffic.

3. Simulation description

3.1 System model

We simulate a WCDMA system with perfect power control in the uplink direction. Users' mobility is not modeled. Hence, a single cell is adequate for this scenario. The interference for other adjacent cells is modeled by the other cells to own cell interference ratio i , [1].

3.2 Traffic modeling

There are two important parameters to simulate traffics in a telephone system. The first parameter is the average call arrival. It is used to describe the average number of calls in a period, modeled as an independent Poisson process [4] with mean arrival rate λ per hour. The value of the average call arrival depends on the assumption. For example, if a system during the busy hour is considered, the average call-arrival rate should be higher than the rate during the off-peak hours. This simulation uses a wide range of values, i.e. 250-1200 average voice-calls per hour. All traffics in this simulation are modeled as the Poisson process.

The second parameter is the average call holding time, modeled as an exponential-distribution random variable. This parameter describes the period that a call holds the channel. The value of this parameter depends on two factors, i.e. the assumption of users' behaviors in a particular period of a day, and types of traffics. The average call holding time in a busy hour should be shorter

than the average call holding time in the off-peak hours. The average call holding time also depends on the types of traffics. The average call holding time of voice traffic is likely to be longer than the average call holding time of data traffic.

3.3 Traffic types

There are three types of traffics in this simulation, i.e. voice traffics, handover traffics and data traffics. The bit-rate and required SIR of both voice-traffic and handover traffic are the same, i.e. 12.2 kbps and 7.0 dB, respectively. The data traffics require data rate of 64 kbps and SIR of 5.0 dB, [1].

Traffic parameters, mentioned in Section 3.2, of both handover-calls and data-calls depend on traffic parameters of voice-calls. Table 1 summarizes the relations between those parameters.

	Average number of calls per hour (μ)	Average call holding time (λ)
Voice traffic (v)	μ_v	λ_v
Handover traffic (h)	$\mu_h = \mu_v / 2$	$\lambda_h = \lambda_v / 2$
Data traffic (d)	$\mu_d = \mu_v / 5$	$\lambda_d = \lambda_v / 12$

Table 1 Relation between traffic parameters

From Table 1, the total number of calls per hour, μ_{total} , can be expressed as the following Equation:

$$\mu_{total} = \mu_v + \mu_h + \mu_d \quad (7)$$

Form Table 1 and Equation 7, the total number of calls per hour can be calculated as following:

$$\mu_{total} = \mu_v + \frac{\mu_v}{2} + \frac{\mu_v}{5} \quad (8)$$

Hence,

$$\mu_{total} = 1.7 \cdot \mu_v \quad (9)$$

Form Equation 8 and 9, it can be concluded that the traffic in this simulation comprises 58.82% of voice-traffic, 29.41% of handover-traffic, and 11.76% of data-traffic.

4. Admission control algorithm

Two admission control algorithms are simulated in this simulation. The first algorithm is the load based admission control. This algorithm measures the load factor and uses a selected load factor value as the admission threshold. The second algorithm is the noise-rise based admission

control. This algorithm measures the noise-rise and uses a selected noise-rise value as the admission threshold. Although both algorithms measure different entities and use different types of threshold value, they are based on the same admission policy. A new call is admitted if the following condition is satisfied:

$$\eta_{ul} + \Delta\eta_j < \eta_{th} \quad (10)$$

when $\Delta\eta_j$ is the load factor generated by the j -th call and η_{th} is the threshold value.

In order to improve the QoS of the system, handover-traffics are given higher priority than other traffics. Extra capacity is reserved for handover traffic. Therefore, handovers call will be accepted if the following condition is satisfied:

$$\eta_{ul} + \Delta\eta_j < \eta_{th} + \eta_{th_ho} \quad (11)$$

when η_{th_ho} is the reserved capacity for handovers.

5. Simulation result

There are four types of results to be presented in this section. They are listed as following:

1. New call blocking probability (BP), handover call dropping probability (DP), and data call blocking probability (D-BP) versus average numbers of users, and thresholds, respectively.
2. Figures of the noise-rise level.
3. Waste-capacity factor, the ratio of the maximum load and average load divided by the maximum load.
4. Average interference in the system. This will be expressed as the average noise-rise.

5.1 Blocking probability and dropping probability versus average numbers of users

Table 2 summarizes parameters used in this section.

Simulation parameter	Value
Average number of voice user	250 - 700
Average call holding time	120 sec.
Threshold	2.5 dB
Admission control algorithm	Noise-rise based
Reserved capacity for handovers	5%

Table 2 Simulation parameters for section 5.1

It is reasonable expecting that both BP and DP grow as an increase of average number of users. Moreover, the result

is expected that DP must be lower than BP because of the reserved capacity for handover-calls.

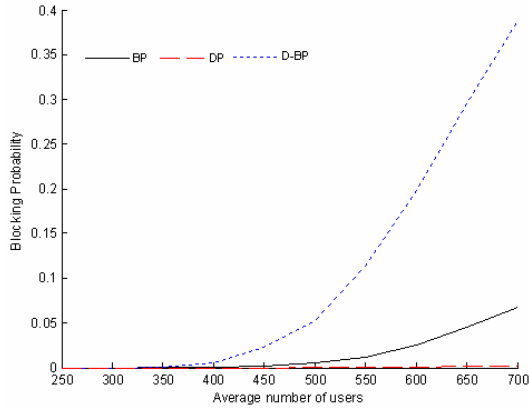


Figure 3 BP and DP versus average numbers of users

In Figure 3, DP is lower than BP as the expectation. However, when the traffic increases, DP grows slowly while BP rises rapidly. This difference is due to the reserved capacity for handover-calls. Handover-call traffic can share the same resource as other traffics when the total load in the system is low. In the light traffic situations, such as when average number of users below 450 users per hour in Figure 3, BP and DP of voice-calls are almost zero because the system is not in congestion. The system can accept most voice calls and handover calls. On the other hand, in a congested situation, BP diverts from zero, while DP is still just above zero. This is because, although the noise-rise reaches the threshold, handover-calls still can access the system because of the reserved capacity. Only handover traffics can utilize the reserved capacity, while other traffics are blocked. The following Figure depicts the mentioned situation.

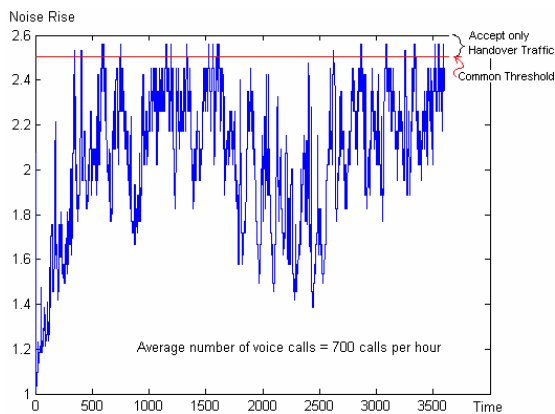


Figure 4 Handover traffic over the threshold

Figure 4 shows that a few numbers of calls are over the common threshold (at 2.5 of the noise-rise level). All of

the traffic over the threshold are handover-traffics. This means that other traffics are blocked, and only handover-traffics can cause congestion in the reserved region. As a result, fewer calls are dropped.

In Figure 3, the blocking probability of data calls (D-BP) rises dramatically as the average number of calls increase. This is because data traffic requires the system a high load, that is, approximately fifth-times of the load required by voice traffic (calculated by Equation 1 and parameters described in Section 3.3). As a result of the high load requirement, a large number of data traffics is blocked, especially when the system is in a congestion.

5.2 Blocking probability and dropping probability versus thresholds

Table 3 summarizes parameters used in this section.

Simulation parameter	Value
Average number of voice user	700
Average call holding time	120 sec.
Threshold	2.2 – 3.0
Admission control algorithm	Noise-rise based
Reserved capacity for handovers	5%

Table 3 Simulation parameters for section 5.2

It can be expected that the blocking probabilities decrease as the threshold increases. The following simulation result depicts BP, DP, and D-BP when the threshold is changed:

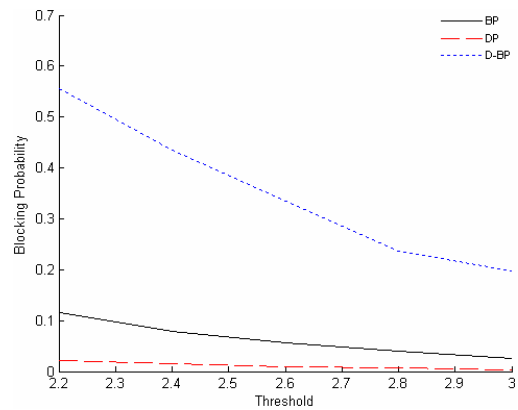


Figure 5 Blocking probabilities versus thresholds

From Figure 5, both BP and DP decrease when the threshold grows. This is due to a CAC with higher threshold allows more traffic to access into the system. Therefore, many calls are accepted resulting in reductions of blocking probabilities.

The blocking probability of data traffic drops dramatically when the threshold increases. The data traffic creates high load (approximately fifth times of voice traffic) into the radio channel. When the threshold is low, the system's capacity is not likely to be enough for admissions of the data traffic. On the other hand, a system where allows high interference is capable for accepting much traffic including data traffic.

Although a higher threshold value results in less blocking probabilities, too large value can cause the system the QoS degradations. If a system has a high threshold, the system is capable for accepting much traffic including data traffic. Less blocking probabilities may lead a system to have higher level of QoS. However, a system with high threshold value allows much traffic into the system. The higher traffic causes larger interference. High interference results in low SIR for all users in the system. The low SNR means high bit-error-rate (BER). High BER is low QoS. Therefore, the system has to find a threshold that can make a balance between the blocking probabilities and the interference level. This threshold is the optimal threshold.

As the threshold expands, the average load factor grows. This situation is illustrated in Figure 6.

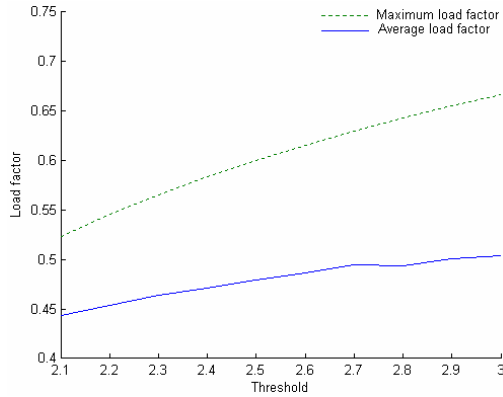


Figure 6 Average load and maximum load

From Figure 6, the maximum load factor and the average load factor increases in the same trend. However, when the threshold is high e.g. 3, the difference between those two factors becomes greater. From Figure 5, D-BP is still quite high at the threshold of 3. The results from Figure 5 and 6 indicate that the system blocks much data traffic, while the capacity is still available. To analyze this phenomenal, the “waste-capacity” factor, v , will be introduced.

The waste-capacity factor is expressed as:

$$v = \frac{\text{Maximumload factor} - \text{Averageload factor}}{\text{Maximumload factor}} \quad (12)$$

Figure 7 shows the waste-capacity factor versus thresholds.

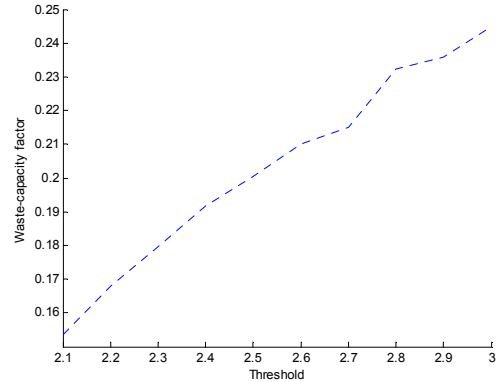


Figure 7 The waste-capacity factor versus thresholds

From Figure 5, 6, and 7, we can see that the data traffic is blocked while the capacity is still available. Keep in mind that data traffic is delay-tolerant, these notify that a system with multi-types of traffic requires a mechanism such as packet scheduling, or queuing to handle data traffic. It is expected that such mechanisms can reduce the waste capacity.

Form Figure 6, as the threshold increase, the average load factor of the system grows. High value of average load factor means the resource is utilized densely. However, a larger number of users sharing the resource gains the system's interference. The gained interference can be expressed as the average noise-rise:

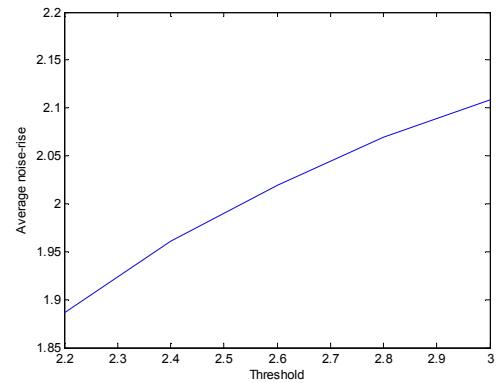


Figure 8 Average noise-rise versus thresholds

Figure 8 shows the gained interference in the term of the average noise-rise. The average total interference raised by multiple users sharing the channel increases in the same pattern as the increase of the load factor shown in Figure 6. Thus, although higher threshold values lead the resource utilization to be more efficient, high thresholds extend the system's interference.

5.3 Comparison between load based CAC and noise-rise based CAC

In this section, BP, DP, and D-BP obtained from the load based call admission control (LB-CAC), and the noise-rise based call admission control (NB-CAC), respectively, are examined.

Parameters used in this Section are summarized in the following Table 4:

Simulation parameter	Value
Average number of voice user	800 - 1200
Average call holding time	120 sec.
Threshold	2.5 for NB-CAC 0.6 for LF-CAC
Admission control algorithm	NB-CAC and LF-CAC
Reserved capacity for handovers	5%

Table 4 Simulation parameters for Section 5.3

The threshold of 2.5 time of the noise-rise is mapped into 0.6 of load factor according to Equation 5. The following Figure illustrates the simulation result.

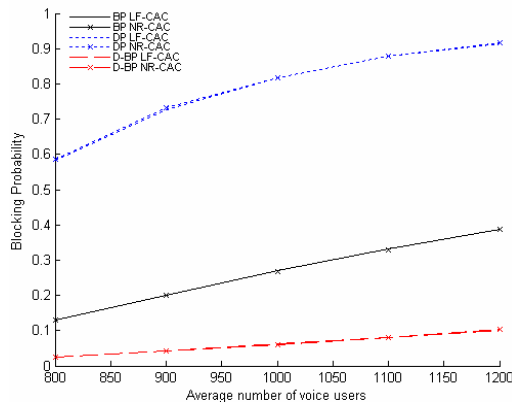


Figure 8 Comparison between LF-CAC and NR-CAC

From Figure 8, there are no significant different between the blocking probabilities of LF-CAC and NR-CAC. The result reveals that if the threshold is mapped appropriately, both CAC algorithms provide the same result.

6. Conclusion

This report overviews some principles of the load calculations in the WCDMA system. It focuses on the load factor calculation and the noise-rise calculation based on [1]. Basic traffic modeling based on [4] is also

presented. After that, the report explains two simple call admission control algorithms. The simulation results show that DP is much lower than BP because of the reserved capacity for handover calls. D-BP is high although the system's capacity is available. This high D-BP leads to a conclusion that the multi traffic WCDMA system requires a particular mechanism to handle the data traffic. The results also show that although high threshold leads the system to have high resource utilization, the noise-rise increases according to the increase of the threshold. Finally, LF-CAC and NR-CAC show the same result.

7. Future works

This simulation has many topics to be developed.

7.1 More realistic channel modeling

The scenario in this simulation is a single cell WCDMA, and it does not have the mobility of users. Therefore, the users' mobility and multiple cells environment can be improved in the next version of this simulation.

7.2 Mechanism to handle data traffic

From Figure 3, 5, and 8, D-BP is high, while BP and DP are low. This means that the system still has capacity, but the capacity is not enough for bearing data traffic. The data traffic can be delayed, and can be scheduled. Therefore, if the simulation system has some mechanisms such as packet scheduling and queuing, the system's resource can be utilized more effectively.

8. Reference

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